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AN EVOLUTIONARY PERSPECTIVE ON GOAL SEEKING AND ESCALATION OF COMMITMENT

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Abstract

Maximizing the probability of bypassing an aspiration level, and taking increasing risks to recover previous losses are well-documented behavioral tendencies. They are compatible with individual utility functions that are S-shaped, as suggested in Prospect Theory (Kahneman and Tversky 1979). We explore evolutionary foundations for such preferences. Idiosyncratic innovative activity, while individually risky, enhances the fitness of society because it provides hedging against aggregate disasters that might occur if everybody had pursued the same course of action. In order that individuals choose the socially optimal dosage of innovative activity, the individuals' preferences should make them strive to improve upon the on-going convention, even if it implies taking gambles that reduce their expected achievements. We show how, in a formal model, the preferences that will be selected for in the course of evolution lead to maximizing the probability of bypassing an aspiration level. Furthermore, when comparing choices with the same probability of achieving this goal, preference is indeed established by maximizing the expected utility of an S-shaped utility function – exhibiting risk loving below the aspiration level and risk aversion beyond it.

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Keywords: evolution of preferences, escalation of commitment, goal-seeking, aspiration level, Prospect Theory, S-shaped utility function, risk-loving, aggregate risk

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1 Introduction

Escalation of commitment is typical to human decision making in a wide range of circumstances. When people make consecutive choices under risk and find themselves losing in the first rounds, they often tend to choose riskier actions, with negative expected gains, if there is a positive chance to make up for some of their previous losses (Janis and Mann (1977), Staw (1997)). Investors are reluctant to realize their losses in the stock market, and hold losing investment too long, hoping they would "bounce back" (Shefrin and Statman 1985, Odean 1998, Weber and Camerer 1998). Bowman (1980, 1982) finds indications that troubled firms take riskier decisions than successful firms. Towards the end of the day, racetrack gamblers tend to shift their bets to longshots, which have the potential of swiftly covering their losses earlier that day (McGlothlin 1956, Ali 1977). Workers do not cut down their consumption when their salary is reduced (Shea 1995), which effectively amounts to betting that their wage will be augmented in the future and compensate for the current relative over-spending. (Bowman, Minehart and Rabin 1999). People who purchased full-price theater tickets attended plays in greater number than people who purchased equivalent tickets at a discount (Arkes and Blumer 1985), thus exhibiting the "Sunk-Cost Fallacy".

Escalation of commitment is tied to a target or goal that the decision maker strives to reach, even by exposing herself to a risk of increasing losses. Risky actions may then be judged primarily by the probability of achieving this aspiration level. Such a "goal seeking" type of behavior was demonstrated for example by Camerer et al. (1997). They found that taxi drivers choose their work hours according to a daily goal of income or length, and stick to it in good days with many clients as well as in weak days with few clients. This behavior violates not only the permanent income hypothesis (which may not be that surprising) but also the maximization of short term utility. Another example is the definition given by chief financial officers of Fortune 500 firms to the term "risk" as "the probability of not achieving the target rate of return" (cited in De Bondt and Makhija 1988). The same definition is reported by Mao (1970), and it also came up as the result of a suitable experiment (described in Libby and Fishburn (1977)).

Escalation of commitment and goal seeking are compatible with Kahneman and Tversky's (1979,1981) Prospect Theory. The theory uses an S-shaped utility function, where the inflection point is at the decision maker's reference point. With such preferences individuals become risk loving after a loss, and are willing to take bets in which they lose on average but have the potential of recovering the loss. Escalation of commitment follows since the bigger the loss, the bigger the stakes which are needed and accepted in order to recapitulate it (Thaler (1980), De Bondt and Makhija (1988)).

Prospect theory is also compatible with many other observed biases (see e.g. Camerer 2000), especially with its further refinement on cumulative, non-linear probability assessments (Kahneman and Tversky 1992) . In the Security-Potential/Aspiration theory of

Lopes and Oden (1999), such weighting of probabilities is augmented by an explicit criterion of achieving an aspiration level with a high probability. They show that in certain contexts, their theory's predictive power supersedes that of Prospect Theory.[1]

The above-mentioned models are descriptive - they deliver predictions on the way people behave, but they do not explain *why* they behave in this way. Recently, an emerging literature (see e.g. Heifetz and Spiegel 2000 and the references therein) tries to use evolutionary processes to explain and endogenize preferences. According to this approach, the preference relation itself is a property which was selected for by evolutionary pressures under varying conditions. The first step in a typical model of this kind is to define the conditions under which the preferences have been formed along the history. Those conditions determine the characteristics of the selected preferences which are observed today, even if the current conditions are already different than the historical ones.

Some of these models discuss the evolution of attitudes towards risk. Dekel and Scotchmer (1999) show that with "winner takes all" games (where the individual with the highest payoff is the only one to reproduce), preference for "tail-dominant" gambles will take over. Robson (1996b) uses a version with a weaker benefit to the winner, and shows that the selected types may like fair bets, i.e. they are not necessarily risk averse. Robson (1996a) shows that in the presence of aggregate risk, preference for dominated gambles may emerge – the selected type is strictly less averse to idiosyncratic risk than to risk which is correlated across all individuals. Bergstrom (1997) shows how the presence of aggregate risk induces preference for mixed strategies.

In this paper we propose a possible insight for the evolutionary emergence of goal-seeking and escalating behavior. Like Robson (1996a) and Bergstrom (1997), we build upon the discrepancy between individual and social motives in the presence of aggregate risk. In such a setting, diversification across individuals makes society more immune to aggregate risks which menace beaten-track courses of action. It is socially beneficial that individuals invest *some* of their resources in idiosyncratic new directions, even if on average these explorations yield, for each individual, less than the mainstream convention.

For example, it is not advisable that everybody grows wheat exclusively in the same, state-of-the-art technique, because that technique might nevertheless become vulnerable to some new decease which is yet to appear. Rather, it is preferable that individuals devote a part of their field to experimenting with their own ideas on wheat cultivation. Some of these ideas will supercede the convention, and become tomorrow's standard. But

[1]There are also earlier attempts in the literature to devise a concise model congruent with types of behavior which are incompatible with von-Neuman Morgenstern expected utility theory. Friedman and Savage (1948) used local convexity of the utility function to explain the co-existence of the demand for both insurance and gambling. Markowitz (1952) used local convexities with a wealth dependent reference point, assuming that the rich have a higher reference point than the poor. This assumption enabled solving few difficulties in the Friedman and Savage model. More generally, Landsberger and Meilijson (1990) introduced "star-shaped" utility functions. Such functions can have local convexities, and the induced preference relation is compatible with "reasonable" partial preference orders on gambles. In particular, such utility functions are compatible with buying lotteries and insurance at the same time.

even if most new techniques yield less wheat than the current standard, at least some of them will yield wheat which is immune to the new decease, simply by virtue of being different.

Thus, individual experimentation can provide beneficial hedging against social aggregate risks. However, such experimentation may be very risky in individual terms. While the idiosyncratic risks of the individual experiments are, by and large, diversified away in aggregate terms in a large population, each individual bears it in full. In individual eyes, the risk of producing less if the experiment fails, and consequently supporting less descendants, may be substantially bigger than the risk of some future decease which appears only once in a dozen generations. This possibility might be so remote that in practice, the individual may not even be aware of this collective danger.

How can, therefore, individuals be "induced" to choose the socially optimal dosage of experimentation in such settings? What preferences for gambles should be "hard-wired" in their brains to this effect? This is the question which we are out to explore in this work. It is a vital question because when preferences are inherited by descendents, we show that in the long run individuals with the socially optimal preferences will almost surely outnumber individuals with other preferences.

What we find is that the optimal preferences imply, indeed, goal-seeking and escalating behavior. The individuals of the victorious type are decisive in their wish to improve upon their current situation and bypass a certain aspiration level. They derive enormous satisfaction from fulfilling this aspiration, and the hope for this fulfillment overshadows in their minds the risks in the involved choices. They are thus risk loving as long as they are below the aspiration level, and risk averse beyond it. Technically, they evaluate gambles with an S-shaped utility function, which has "an infinite jump" at the aspiration level.

Such preferences turn to be socially optimal because they combine two balancing features. On one hand, individuals set up their aspiration level somewhat above their current status, and therefore their choices will always involve some positive degree of experimentation (as socially commanded), since this is the only way which can lead them to fulfil their aspirations with a positive probability. Thus, *the social motive of hedging against aggregate risks is fulfilled by the individual motive to improve one's status in life.* On the other hand, individuals are nevertheless risk averse when they compare outcomes beyond their aspiration level. This leads them to limit the amount of experimentation in their action portfolio, which is again in line with the social interests: After all, hedging against collective risks impedes growth most of the time, and it is therefore socially desirable only to a limited extent.

Our model is akin to that of Bergstrom (1997). In the model, individuals confront in their lifetime one out of a host of decision problems, all with a similar structure. In each of them, the individuals have to decide how to divide their resources between two actions: The conservative one, which ensures a good outcome (normalized to 1) in good times, but very rarely, in bad times, yields nothing; and the innovative one, which turns sour (less than 1) more often than it turns sweet (more than 1), but irrespective of whether the times are good or bad for the conservative action. The number of descendents each individual has is linear in the above outcome, and these descendents inherit the preferences of the parent.

For each of the decision problems, we show how to calculate the "Gene's optimal choice", where the Gene is a metaphorical entity interested in maximizing the long term growth of its carriers, and the choice is a division of the resources between the conservative action and the innovative action. To this effect, we devise the Gene with a utility function (which depends on the parameters of the problem), the maximization of which yields that optimal choice. We show that the Gene's utility function indeed represents the interests of the Gene in a strong sense: If every generation faced the same problem, and one choice is better than another according to the Gene's utility function, then a sub-society that consistently makes the inferior choice will almost surely become asymptotically extinct relative to a sub-society that sticks with the superior choice.

The environment in our model is not invariant, though, so for maximizing long-term prosperity it is not enough to pass from generation to generation just one recipe of one optimal choice. Rather, it is a decision rule that has to be implemented, a rule which results in the Gene's optimal choices in each decision problem drawn from a big family of problems. To achieve this, the Gene should "choose" appropriate preferences to be "planted" in the individuals' minds. These preferences should induce the individuals to make the appropriate choices when they confront the problem of their generation, even though they are not aware of the collective risk associated the conservative course of action, as this risk has materialized, if at all, so many generations ago, and in a somewhat different environment.

Though the story about the Gene selecting individual preferences is only a metaphor, it is a useful one. The optimal preferences from the point of view of the Gene are the ones which the model predicts to persist and take over the population in the long run, in a selection process in which less successful preferences are gradually wiped out by more successful ones. We will show that the persistent preferences all have the same structure – they all cause the individuals to maximize the probability of bypassing a certain aspiration level. Furthermore, the optimal preferences of the individuals can be represented by the expectation of an S-shaped utility function – convex for losses and concave for gains.

The paper is organized as follows. In section 2 we describe the model. Section 3 explores the evolutionary dynamics in constant and in varying environments, and it contains the calculation of the choices that will be preferred by the evolutionary pressures. Section 4 continues with the definition of the optimization problem from the individual's perspective. The characterization of the suitable utility functions is carried out in section 5. Section 6 concludes.

2 The model

Consider a large population of similar individuals in a multi-period world. There are two possible states of nature which may occur at each period – "good" or "bad". The probability of the bad state is drawn independently across periods from some distribution G with average q. The average probability q of the bad state is very close to zero. Thus, the time between two occurrences of the bad state is very large on average.

In each period every individual has to choose how to divide her resources between two actions – a "conservative" action and an "innovative" action. The state of nature determines the payoffs of the actions, and hence also the overall payoff to each mixture of them in the individuals' choices. It is assumed that the population reproduces itself in every period, and the fitness of every individual – the number of her offspring – is linear in her payoff in the same period.

In each period the conservative action yields a payoff of 1 in the good state, and a payoff of 0 in the bad state. Since the state of nature is common to all the individuals in a certain period, the conservative action is socially (or biologically) risky. The innovative action yields the result of the following gamble, independently of the state of nature : a payoff of $1 + c$ with probability p, or a payoff of $1 - c$ with probability $1 - p$, where the parameters $c > 0$ and $0 < p < 0.5$ may change from period to period. The gambles are independent across individuals. As explained in the introduction, they represent idiosyncratic innovative endeavors. By virtue of being different from the conservative action, they are assumed to be unaffected by the danger to the latter in the bad state.

We are particularly interested in cases in which $p < 0.5$, because this means that the expected payoff from the innovative action is less than 1. For low values of p, a risk averse individual will choose to invest her resources only in the conservative action. If everybody chooses to do so in every period, the entire population will be wiped off when eventually a bad state occurs. This contrast between the individual risk and the aggregate risk is a key factor in the model and the results.

The choice of an individual is a mixture $(1 - s,\, s)$ between the two actions. The interpretation we give to such a mixture is that the individual invests parts of her available effort in each of the actions. Consequently, the payoff to the choice is the corresponding weighted average of the actions' payoffs, not of a gamble between the two actions. Thus, in the good state a mixture of $(1 - s,\, s)$ yields a payoff of $1 + sc$ with probability p, and payoff of $1 - sc$ with probability $1 - p$.

	Good State (prob. $1 - q$)	Bad State (prob. q)
Conservative $(1 - s)$	1	0
Innovative (s)	$\begin{cases} 1 + c, & \text{with probability } p \\ 1 - c, & \text{with probability } 1 - p \end{cases}$	$\begin{cases} 1 + c, & \text{with probability } p \\ 1 - c, & \text{with probability } 1 - p \end{cases}$

As explained in the introduction, we assume that individuals are not even aware of the bad state, possibly because it has materialized such a long time ago, and in a somewhat different environment (different c and p).

From a social vista point, on the other hand, things look different. A population of individuals who all choose the mixture $(1-s,\, s)$ will get an average payoff of $1-sc(1-2p)$ in the good state (i.e. with probability $1-q$), and $s-sc(1-2p)$ in the bad state (with probability q). The direct consequences of this are explored in the following section.

3 The evolutionary dynamics

Denote by X_t^s the size of a large population at the beginning of period t, the individuals of which all choose to invest part s of their effort in the innovative action in period t. We assume that the number of offspring of an individual is linear in her payoff. Furthermore, since the population is large, we assume that the strong law of large numbers obtains. Thus, for some coefficient k_t, the random variables X_t^s and X_{t+1}^s are related by[2]

$$X_{t+1}^s = k_t X_t^s \cdot \begin{cases} 1 - sc(1-2p) & \text{good state at } t,\ \text{probability } 1-q \\ s - sc(1-2p) & \text{bad state at } t,\ \text{probability } q \end{cases} \tag{3.1}$$

Assume, first, that the parameters s and c do not change across periods. What is the mixture $(1-s,\, s)$ between the actions which will maximize the size of the population in the long run? Along history, good states appear in portion $(1-q)$ of the periods, and bad states occur in portion q of the periods. Choosing the mixture $(1-s,\, s)$ will therefore yield an average growth rate proportional to

$$F(s) = [1 - sc(1-2p)]^{1-q}\,[s - sc(1-2p)]^q \tag{3.2}$$

Imagine now a Gene as a metaphorical subject, who can "instruct" its carriers to choose a specific mixture $(1-s,\, s)$, and this instruction is inherited by descendents. The Gene is interested in the long term growth rate of its carriers. We now show that the function $F(s)$ represents the "Gene's utility function" in a strong sense: Higher values of F imply, almost surely, relative domination of the population in the long run.

Proposition 1 *For any two different proportions $s, s' \in [0,1]$ of investment in the innovative action, $F(s') < F(s)$ if and only if a population that consistently chooses the*

[2] The coefficients k_t may depend on exogenous conditions (like climate changes or food availability) or even on the size of the entire population $\int_0^1 X_t^s ds$ at time t. The size of k_t will not influence the analysis below, since we are interested in the *relative* success of investment choices and not in the absolute size of the population.

proportion s' will almost surely become asymptotically extinct relative to a population that consistently chooses the proportion s, i.e.

$$\lim_{t\to\infty} \frac{X_t^s}{X_t^{s'}} = \infty$$

almost surely.

Proof. Define the differences

$$\delta_t^{s,s'} = \log \frac{X_{t+1}^s}{X_{t+1}^{s'}} - \log \frac{X_t^s}{X_t^{s'}}. \tag{3.3}$$

According to (3.1),

$$\delta_t^{s,s'} = \begin{cases} \frac{1-sc(1-2p)}{1-s'c(1-2p)} & \text{good state at } t, \text{ probability } 1-q \\ \frac{s-sc(1-2p)}{s-s'c(1-2p)} & \text{bad state at } t, \text{ probability } q \end{cases} \tag{3.4}$$

Summing these differences across periods yields

$$\log \frac{X_t^s}{X_t^{s'}} = \log \frac{X_0^s}{X_0^{s'}} + \sum_{\tau=0}^{t-1} \delta_\tau^{s,s'} \tag{3.5}$$

Since the state of the world – good or bad – is determined independently across periods, the random variables $\delta_t^{s,s'}$ are i.i.d., with expectation

$$E\delta \equiv E\delta_t^{s,s'} = \log F(s) - \log F(s') \tag{3.6}$$

Thus, there are two cases:

(i) $F(s) > F(s')$. In this case $E\delta > 0$, so by the strong law of large numbers

$$\frac{1}{t}\log \frac{X_t^s}{X_t^{s'}} = \frac{1}{t}\log \frac{X_0^s}{X_0^{s'}} + \frac{1}{t}\sum_{\tau=0}^{t-1} \delta_\tau^{s,s'} \xrightarrow[t\to\infty]{\text{a.s.}} E\delta > 0 \tag{3.7}$$

Hence, in this case

$$\frac{X_t^s}{X_t^{s'}} \xrightarrow[t\to\infty]{\text{a.s.}} \infty \tag{3.8}$$

(ii) $F(s) = F(s')$. In this case $E\delta = 0$, and by the central limit theorem we have

$$\frac{1}{\sqrt{t}}\log \frac{X_t^s}{X_t^{s'}} = \frac{1}{\sqrt{t}}\log \frac{X_0^s}{X_0^{s'}} + \frac{1}{\sqrt{t}}\sum_{\tau=0}^{t-1} \delta_\tau^{s,s'} \xrightarrow[t\to\infty]{\text{D}} N(0, var(\delta)) \tag{3.9}$$

where $var(\delta) = var(\delta_t^{s,s'})$. Therefore, in this case $\frac{X_t^s}{X_t^{s'}}$ does not converge to infinity almost surely. ∎

What is, therefore, the mixture $(1-s^*,\ s^*)$ which will maximize long term growth? Proposition 1 implies that s^* is the maximizer of $F(s)$, which is

$$s^* = \arg\max_{s\in[0,1]} F(s) = \begin{cases} \frac{q}{c(1-2p)} & \text{for } p \in (0, \frac{1}{2} - \frac{q}{2c}) \\ 1 & \text{for } p > \frac{1}{2} - \frac{q}{2c} \end{cases} \tag{3.10}$$

The following graph depicts s^* as a function of p:

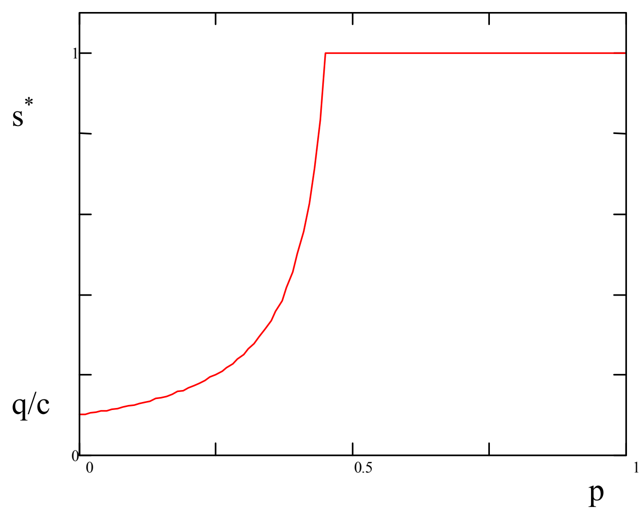

FIGURE 1. THE SOCIALLY OPTIMAL LEVEL OF INVESTMENT s^* IN INNOVATION AS A FUNCTION OF ITS SUCCESS PROBABILITY p

Inverting this relation we get that

$$p = \frac{1}{2} - \frac{q}{2s^*c} = \frac{s^*c - q}{2s^*c}, \quad \frac{q}{c} < s^* < 1. \tag{3.11}$$

If each generation had been facing exactly the same decision problem (with some fixed, specific parameters p, c, q), the “design problem” for the Gene would have been relatively simple: All that would have been needed is to “program” the individuals to consistently devote the proportion s^* of their resources to experimentation.

However, the environment does change from generation to generation. In our model, the parameters p, c, q may be different across periods. What has to be "programed" and inherited by descendents, therefore, is a *decision rule which will induce them to choose the appropriate s^* as a function of the parameters p and c that they can assess.* In the next section we shall show how this can be done by endowing individuals with a suitable utility function.

4 The individual perspective

As explained in the introduction, we assume that individuals are unaware of the bad state of nature associated with their decision problem. Although bad states have appeared, in most of the periods such occurrences are way far in the past, and associated with environments which are different than the current one.

Thus, we assume that individuals choose that division of resources between the actions which maximizes the expectation of their utility V from the payoffs they perceive as possible in the good state. With the mixture $(1-s,\, s)$, these payoffs are $1+sc$ when the innovative action is successful (probability p) and $1-sc$ when it fails (probability $1-p$). The individual maximization problem is therefore given by

$$\max_{s\in[0,1]} pV(1+sc) + (1-p)V(1-sc) \tag{4.1}$$

Suppose that the utility function V is inherited by descendents (possibly by a combination of biological reproduction and education). Proposition 1 implies that individuals with a utility function for which

$$s^* = \arg\max_{s\in[0,1]} \left[pV(1+sc) + (1-p)V(1-sc)\right] \tag{4.2}$$

for every combination of parameters p and c will take over the population in the long run. This is because they will choose the socially optimal s^* in each and every generation, whatever are the parameters of the decision problem to face. In metaphorical terms, a way for the Gene to implement its desired decision rule is to endow individuals with such a utility function.

When $s^* \in (\frac{q}{c}, 1)$, substituting (3.11) in the first order condition for (4.2) yields

$$\frac{V'(1+s^*c)}{V'(1-s^*c)} = \frac{1-p}{p} = \frac{1-\left(\frac{1}{2}-\frac{q}{2s^*c}\right)}{\frac{1}{2}-\frac{q}{2s^*c}} = \frac{s^*c+q}{s^*c-q}, \quad \frac{q}{c} < s^* < 1. \tag{4.3}$$

By substituting $x = s^*c$, this relation becomes

$$\frac{V'(1+x)}{V'(1-x)} = \frac{x+q}{x-q}, \quad q < x < c. \tag{4.4}$$

We should now verify that a utility function which satisfies the first order condition (4.3) achieves indeed a maximum at s^*.

Claim 1 *Every strictly increasing and twice continuously differentiable utility function V which satisfies (4.3) achieves a maximum at s^* when (4.3) is satisfied*

Proof. Substituting (3.11) into the first order condition (4.3) yields

$$\left(\frac{1}{2}-\frac{q}{2s^*c}\right)V'(1+s^*c)+\left[1-\left(\frac{1}{2}-\frac{q}{2s^*c}\right)\right]V'(1-s^*c)=0, \quad \frac{q}{c}<s^*<1 \tag{4.5}$$

or, equivalently

$$V'(1+s^*c)-\frac{s^*c+q}{s^*c-q}V'(1-s^*c)=0, \quad \frac{q}{c}<s^*<1. \tag{4.6}$$

Since this relation holds in an interval, we can differentiate with respect to s^* and get

$$cV''(1+s^*c)+c\frac{s^*c+q}{s^*c-q}V''(1-s^*c)+\frac{2cq}{(s^*c-q)^2}V'(1-s^*c)=0, \tag{4.7}$$

implying that

$$\frac{s^*c-q}{2s^*c}V''(1+s^*c)+\frac{s^*c+q}{2s^*c}V''(1-s^*c)=-\frac{q}{s^*c\,(s^*c-q)}V'(1-s^*c)<0 \tag{4.8}$$

which is the desired second order condition

$$pV''(1+s^*c)+(1-p)\,V''(1-s^*c)<0. \tag{4.9}$$

■

5 Properties of a suitable utility function V

Equation (4.4) does not pin down a unique utility function V. However, as the following proposition shows, all the suitable functions V have "an infinite jump" at $1+q$. This follows from the hedging requirement that the investment in the innovative action be bounded away from zero (at least $\frac{q}{c}$) even when the probability of success in it is very small ($p \searrow 0$). The smaller this probability p is, the bigger is the relative satisfaction from success which is needed in order to induce the individual to follow the socially optimal behavior.

Proposition 2 *For every strictly increasing function V which satisfies (4.4)*

$$\lim_{y \to 0^+} [V(1+q+y) - V(1+q-y)] = \infty \tag{5.1}$$

Proof. Since s^* in (4.2) maximizes the individual expected utility, we have that for every $s \in [0,1]$

$$pV(1+\frac{q}{1-2p}) + (1-p)V(1-\frac{q}{1-2p}) \geq pV(1+sc) + (1-p)V(1-sc) \tag{5.2}$$

In particular, (4.11) holds for $s = \frac{q-\varepsilon}{c}$ for small enough $\varepsilon > 0$:

$$pV(1+\frac{q}{1-2p}) + (1-p)V(1-\frac{q}{1-2p}) \geq pV(1+q-\varepsilon) + (1-p)V(1-q+\varepsilon), \tag{5.3}$$

that is

$$V(1+\frac{q}{1-2p}) - V(1+q-\varepsilon) \geq \frac{1-p}{p}\left(V(1-q+\varepsilon) - V(1-\frac{q}{1-2p})\right). \tag{5.4}$$

Letting $p \searrow 0$, and using the fact that V is increasing, we get

$$\lim_{p \to 0^+}\left(V(1+\frac{q}{1-2p}) - V(1+q-\varepsilon)\right) \geq \lim_{p \to 0^+}\frac{1-p}{p}\left(V(1-q+\varepsilon) - V(1-\frac{q}{1-2p})\right) \tag{5.5}$$

$$\geq \lim_{p \to 0^+}\frac{1-p}{p}\left(V(1-q+\varepsilon) - V(1-q)\right) = \infty$$

Hence, for small enough $\varepsilon > 0$

$$\lim_{x \to q^+}\left(V(1+x) - V(1+q-\varepsilon)\right) = \infty, \tag{5.6}$$

and since V is strictly increasing, (5.1) follows. ■

Strictly speaking, V cannot have "an infinite jump" at $1+q$ and be strictly increasing in the entire domain. However, we can have two branches for V – to the left and to the right of $1+q$. The left branch will tend to $+\infty$ when approaching $1+q$ from the left, and the right branch will tend to $-\infty$ when approaching $1+q$ from the right. By adding a sufficiently large, finite constant to the right branch, V can be well defined and increasing outside an arbitrarily small interval around $1+q$. This definition will then be sufficient in order to compare the expected utility of gambles with finitely many outcomes (different than $1+q$). With this usage of V, the preferences over such gambles are thus well defined. These preferences are lexicographic:

1. Gamble X will be preferred over gamble Y if X gives a higher probability of getting more than the aspiration level $1+q$. This goal is slightly above the outcome 1, which the individuals believe can be assured by taking the conservative action.[3] This is the sense in which the individuals are decisive in their desire to do better and bypass the current "status quo".

2. If the two gambles yield the same probability of bypassing the goal $1+q$, their expected utility has to be compared. This expected utility is the sum of the expectations over the two branches of the utility function – to the left and to the right of $1+q$. In this case, the comparison of the expectations is not sensitive to the large finite jump assumed in the passage from the left branch to the right branch.

A simple such solution to (4.4) is attained from the pair of equations

$$\begin{aligned} V'(1+x) &= \frac{1}{x-q} \\ V'(1-x) &= \frac{1}{x+q} \end{aligned}$$

which yield

$$V(y) = \begin{cases} +M + \log\left[y-(1+q)\right] & y > 1+q+\varepsilon \\ -M - \log\left[(1+q)-y\right] & y < 1+q-\varepsilon \end{cases}$$

where $\varepsilon > 0$ is arbitrarily small, and M is large enough to make V increasing.

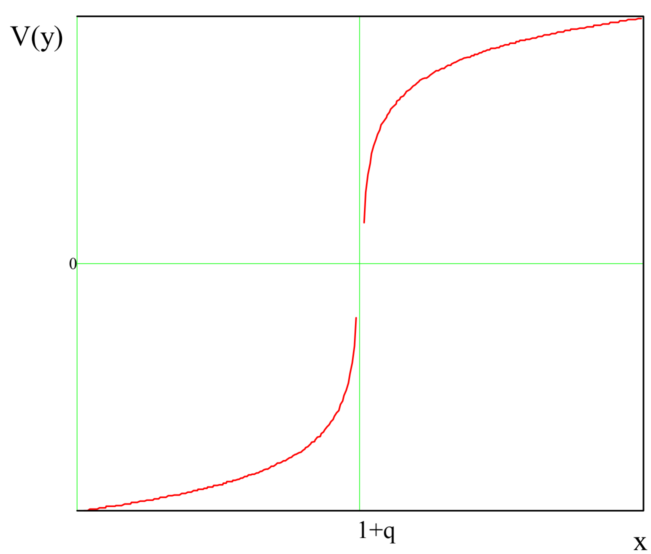

FIGURE 2. A FITNESS-MAXIMIZING UTILITY FUNCTION

[3]Recall that the average probability q of the bad state is assumed to be very small, and that the individuals are not aware of the possibility of such a bad state.

This utility function is "simple" in the sense that it does not have any inflection points other than the critical point $1+q$. It is straightforward to see that any V with branches to the left and to the right of $1+q$, which can be made strictly increasing by excluding an arbitrarily small interval around $1+q$ and adding a large enough jump between the branches – such a V is "simple" in the above sense only if it is convex to the left of $1+q$ and concave to the right of $1+q$.

From the point of view of the Gene, such simplicity is a desirable feature when "designing" the individual utility function. The qualitative features of the preference relation are very simple: lexicographic preference for bypassing the status quo and achieving more than a modest improvement goal, risk loving below this aspiration level and risk aversion beyond it. Quantifying these simple rules of thumb into preferences in individuals' minds is presumably simpler than hard-wiring preferences that involve qualitative twists at more than one threshold level (as would be required for utility functions with more inflection points).[4]

The simple suitable functions are thus S-shaped, as suggested in Prospect Theory (Kahneman and Tversky 1979,1981). The "infinite jump" expresses a leading criterion of bypassing a certain minimal achievement. This reference point is slightly higher than what can be ascertained by a "default" action, and thus expresses a constant desire to improve upon one's situation. Such preferences are congruent with behavior patterns that are usually associated with Prospect Theory – goal seeking, the sunk cost fallacy and the escalation of commitment.

6 Conclusion

We confined ourselves to a minimal model in order to allow for sharp, analytic results. We preferred simplicity over richness: Our aim was to point at possible evolutionary forces which push towards a *specific* type of observed behavior, not to analyze a whole, complex arena in which different forces lead to many (possibly conflicting) behaviors. It is a "reverse engineering" exercise, in which we explore what a commonly observed bias could potentially serve for in the course of evolution. There is no claim here that our findings constitute the unique "explanation" for goal-seeking, nor that goal-seeking is socially optimal in any environment.

As far as we know, our attempt is the first one in the literature to construct an entire utility function on the basis of evolutionary considerations. Hopefully, a similar approach may yield further insights into the foundations of human behavior.

[4] It is probably possible to formalize this evolutionary argument in favor of "simple" preferences by introducing more elaborate evolutionary dynamics, in which "complex" suitable mutations are less likely to appear than "simple" ones. It is outside the scope of this work, in which we have confined the discussion to a straightforward selection process.

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